CONSTRUCTION OF COLD IN PLACE RECYCLING METHOD IN MALAYSIA

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ABSTRACT

Economic and environmental considerations have prompted the Cold In Place Recycling (CIPR) in the last three decades. Today, the humanity is very conscious preserving the environment. In this aspect, CIPR is being pursued as one of the rehabilitating deteriorating method in Malaysia since the greatest savings occur when trucking costs are eliminated. CIPR was often called as stabilisation in various methods which included rippers, scarifiers, pulverize and stabilizing agents to reclaim the existing asphalt together with base layer. Foamed bitumen, bitumen emulsion and other rejuvenators have been added followed by screeding and compaction of the reprocessed material in one continuous operation. It is usual for a single machine to complete one kilometre of full-width road rehabilitation in a day, although a more conservative figure of 5000 m^2 is normally used for planning purpose. To derive the maximum benefit in maintenance, CIPR operations need to be managed to ensure that the output consistently meets the specified requirements. The performance of the rehabilitation through CIPR method is contingent to represent the assumptions made for predicting the life of the rehabilitated pavement and any shortfall in either could lead to premature failure. The cost of the maintenance resulted from the proper construction process.

1.0 INTRODUCTION

1.1 Background

Road has been gazetted as one of the government assets which need to be facilitated as to serve the functional factor and provide a comfort zone for road users. Malaysia is relatively a small country of 13 states, which are linked by about more than 120,000 kilometres of paved roads [4]. Most of these roads were designed for twenty (20) to thirty (30) years ago and have well passed its designed years. Overlays of 40mm to 60mm Asphaltic Concrete Wearing Course (ACWC), mill and replace and reconstruction had been the conventional and common methods to rehabilitate the existing paved roads. [2]

The location of Malaysia is situated in the tropics with a tropical climate and rainfall all year round. Rainfall is heavy and usually occurs in the form of thunderstorms followed by flood and the roads will submerge for few days with annual rainfall measures around 2000mm. [6] Most of the road defects after the flooding season contribute to the structural failure especially for the base layer. For centuries man has relied heavily on roads in one form or another as the primary means of communication and transport. The development of motorised transport has had a huge impact on the need to provide appropriate road networks. Inevitably these roads reach the end of their structural lives. They become cracked, potholed, and bumpy, attracting public outcry for speedy repair and, in many countries, road authorities are now placing far more emphasis on maintenance and rehabilitation than on the development of new roads. These two factors lead to the finding of new methodology of rehabilitation and introduced CIPR as an effective technique.

Since mid 80's the recycling technique was first introduced in Malaysia, as one of the concept of alternative road rehabilitation. Although Cold In-Place Recycling began in Malaysia some 20 years ago, it was not until 1993 when the private sectors pursued the matter seriously by acquiring purpose-built recycling machines from Germany, the United States and Canada. The growth of the recycling technology in the country had driven private sector with a strong support from the government through the Public Works Department of Malaysia to accommodate the federal roads in Malaysia with the same technology.

Full Depth Reclaimed (FDR) is a technique where all the asphalt pavement section and a portion of the underlying materials are processed together to produce a stabilized base course. The materials are recycled and additives are introduced; materials are then shaped and compacted before asphalt surfacing (ACBC and ACWC) is applied. One of the advantages of the FDR is cost savings of up to 40 percent over conventional techniques. In the USA, nearly 30 million tons of reclaimed asphalt pavements are recycled, saving taxpayers more than $300 million annually. [7]

Although the FDR technique is gaining acceptance as a cost effective solution in rehabilitating distressed pavement, very little local research has been carried out on its cost-effectiveness, design, construction and long term performance. Subsequently, the Public Work Department (JKR) has embarked on a research work in this field, in collaboration with Kumpulan Ikram and Roadcare Sdn. Bhd. It is hoped that this study will lead to an establishment of a comprehensive design and construction guidelines on FDR for Malaysia, as well as characterise its fundamental materials and layer parameters.

1.2 Objectives

The objective of this paper is to highlight the construction process of CIPR. The paper describes the methodology, machineries and economical way to sustain and maintaining the rehabilitated pavement through CIPR method.

2.0 DEVELOPMENT OF CIPR IN MALAYSIA

The government of Malaysia privatized the maintenance of its Federal Roads in 2001 with a 15-year privatization program started with 12,000 kilometres of the Federal Road network. The network was divided into three regions, each with a different concession company, and later in 2003, the government privatized the maintenance of another 3,000 kilometres of Federal Roads in East Malaysia.

Through the privatization program, recycling technology has gained greater acceptance and is now considered to be a more cost effective solution to rehabilitate badly deteriorated roads. Over the past 20 years, recycling technology has been used throughout Malaysia to rehabilitate tolled expressways, major highways, rural and village roads with a range of traffic volumes. A few of those projects are summarized in Table 1.

Table 1 . Few of CIPR Projects in Malaysia

Item	Year	Name of Projects	Length (km)	Stabilizing agents	Traffic Volume
1	1985	FT 002, Pahang	15	Cement	L
2	1989	FT 008, Pahang	55	Cement	V.L
3	1994	Jalan Matang, Sarawak	10	Cement	V.L
4	1998	FT 007, Changlun, Perlis	1.8	Cement, Foamed Bitumen	V.L
5	1999	FT 005, Selangor	117	Foamed Bitumen	V.H
6	2001	FT 14, Terengganu	6	Cement	H
7	2002	FT 801, Sarawak	30	Cement	H
8	2002	FT 1581, Pahang	14	Foamed Bitumen	L
9	2002	FT 1210, Selangor	8.6	Cement	L
10	2003	Middle Ring Road 1 Package 1, Selangor	1	Cement, Foamed Bitumen	H
11	2003	FT 2489, Pahang	3.7	Cement	L
12	2004	Jalan Lubuk Panchor	4	Emulsion	V.L
13	2004	FT 801, Sarawak	50	Cement	H
14	2005	FT 1562, Felda Lepar Hilir, Pahang	4.5	Cement,Emulsion, Foamed Bitumen	L
15	2005	FT 1739 Felda Kemahang, Kelantan	4	Cement,Emulsion, Foamed Bitumen	L
16	2006	FT 126, Cherul-Bukit Sagu	7	Cement,Emulsion, Foamed Bitumen	L
17	2006	Felda Pekoti, Pahang	5	Cement,Emulsion, Foamed Bitumen	V.L
18	2006	FT 1534 Felda Jengka, Pahang	4	Cement,Emulsion, Foamed Bitumen	L
19	2007	FT 10 Temerloh-Bera, Pahang	1.5	Cement,Emulsion, Foamed Bitumen	M
20	2007	FT 1502, Felda Krau, Pahang	2.2	Cement, Emulsion Foamed Bitumen	H

3.0 EQUIPMENT SELECTION

The recycling machine and primary compactor are the only two items of plant that are not common to all road construction projects. In addition, equipment used for spreading the low application rates of cement normally specified with foamed bitumen needs careful consideration.

3.1 Recycling With Stabilising Agents

3.1.1 Recycling with cement

Typically between 2% and 4% (by mass) of cement is added during the recycling process when this stabilising agent is used. The cement may be added in three different ways:

- Spread onto the surface of the road ahead of the recycler. In a single operation, the recycler passes over the spread cement, mixing it together with the underlying material;
- Mixed together with water in a specially designed slurry mixer to form slurry that is then introduced directly into the mixing chamber. This ensures accurate application rates and eliminates the wastage of cement, (it cannot blow away in the wind); or
- Applied using a specialised cement spreader incorporated in the recycler's frame.

Behind the recycling machine the recycled layer of material is profiled with a motor grader before being compacted using a vibratory roller. Finally, a rubber tyred roller is normally used to obtain a well-knitted surface finish. Once compaction of the recycled layer has been completed, the road should be surfaced with a bituminous layer. This may vary, depending upon the traffic loading, from a thin surface treatment in the case of lightly trafficked roads, to one or more layers of hot-mixed asphalt when the pavement carries heavy traffic.

The recycling train is depicted in the Figure 1 below.

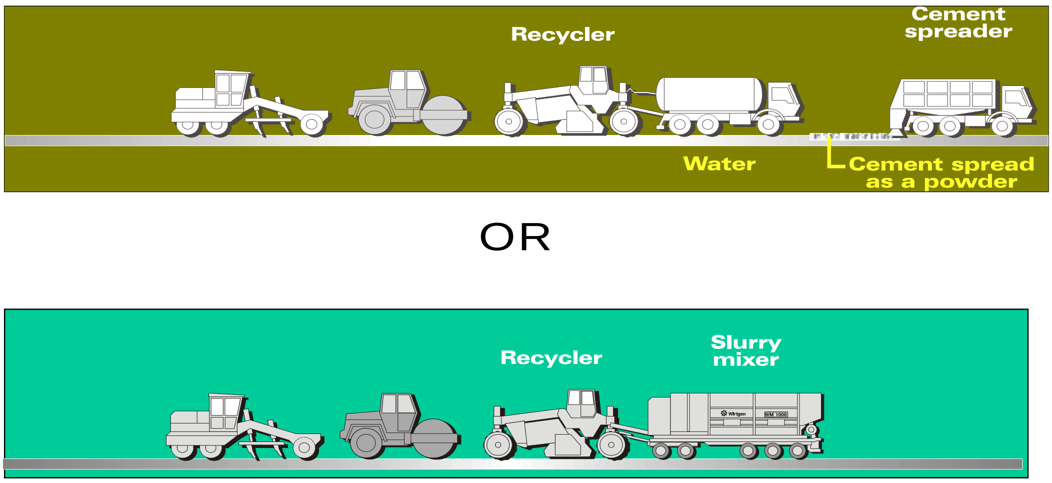


Figure 1. Recycling train for cement.

3.1.2 Recycling with bitumen emulsion

Bitumen emulsion is manufactured by emulsifying bitumen and water, using emulsifying agents. Usually the emulsion contains approximately 60% of bitumen and 40% of water. The advantage of bitumen emulsion is that it is a liquid at ambient temperatures and can be mixed with road-building aggregates without the need to heat the stone and the bitumen, as is the case with hot-mixed asphalt.

When bitumen emulsion is used in the cold in place recycling process, it is transported in a tanker that is pushed ahead of the recycling machine, as shown in the diagram below. The emulsion is delivered to the recycling machine via a flexible hose and sprayed into the mixing chamber of the recycler as it moves forward. The milled material and the bitumen emulsion are thoroughly mixed together in the recycler's mixing chamber before being discharged from the rear of the recycler and profiled using a motor grader. The new layer is then compacted in the same way as the cement treated layer. Typically around 5% (by mass) of bitumen emulsion is added to granular road building materials. However if the existing pavement consists of a thick layer of asphalt, the amount of emulsion can be reduced to between 3% and 4%, depending upon the proportion of asphalt in the mix. A typical recycling train where bitumen emulsion is being used is shown below in Figure 1.

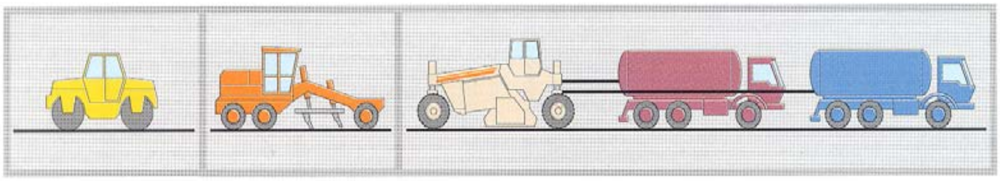


Figure 2. Typical train for bitumen emulsion.

In many cases a combination of bitumen emulsion and cement is found to be effective. The percentage of cement that is added depends on the design approach used and may typically vary from 1% to 3%. It is introduced into the recycled mixture together with the bitumen emulsion using any of the methods described above. The configuration of the recycling train where cement is used together with bitumen emulsion is shown in the Figure 3.

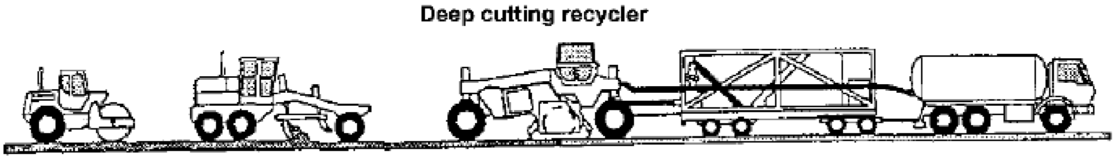


Figure 3. Recycling train where cement is used together.

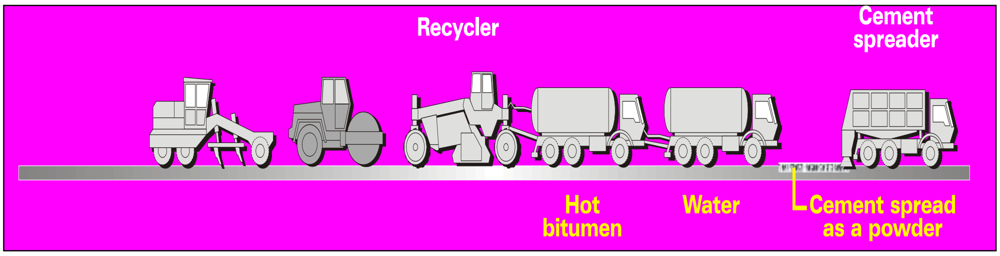
Advantages of using a combination of cement and bitumen emulsion are:

- Improved adhesion of the bitumen to the aggregate;
- More rapid gain in strength, enabling the road to be opened to traffic quicker; and
- Improved ultimate strength of the recycled layer.

2.2.3 Recycling with foamed bitumen

Foamed bitumen is manufactured onboard the recycling machine using a specialized process that adds a small percentage of water to hot penetration-grade bitumen. The foamed bitumen is sprayed directly into the mixing chamber of the recycling machine in the same way as the bitumen emulsion. The foaming process enables normal grades of bitumen to be mixed with cold, moist recycled material without first having to be emulsified. In the case of granular materials, between 3% and 5% of foamed bitumen (by mass) is normally added. When the recycled material contains a high

proportion of asphalt, a reduced content of foamed bitumen of between 2% to 3% is common. As in the case of bitumen emulsion, there are benefits in adding small percentages (typically 1% to 2%) of cement, together with the foamed bitumen. As described above for bitumen emulsion, the cement can be added either as a powder, or as cement/water slurry using a specialised slurry mixer. A typical configuration of a recycling train using foamed bitumen with cement is shown below in Figure 4.



OR

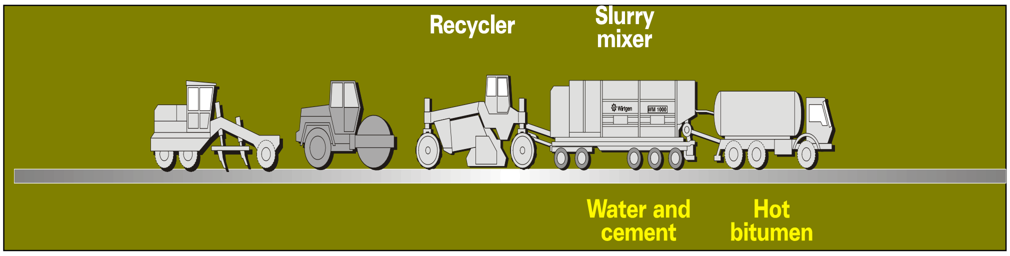


Figure 4. Typical configuration of a recycling train using foamed bitumen.

3.0 PREPARATION OF CONSTRUCTION AREA.

Prior commencement of the works, areas of non-uniform materials or pavement thickness should be identified. Areas with either insufficient pavement thickness or subgrade strength to support the weight of the recycling train should be identified. These areas of insufficient support must be corrected prior to recycling machine or other equipment breaking through the pavement, causing construction delays and added expense. Weak material should be removed and replaced with suitable patching material. Large areas patched with aggregate could require increases in recycling additive for proper coating. The use of Reclaimed Asphalt Pavements (RAP) eliminates this concern. Small aggregate patches are acceptable but will result in some uncoated aggregate.

Since recycling is a high production, fast-track process, logistics need to be addressed in the planning process. To ensure that the reclaimed mix is uniform and productivity remains high, the project has to be continuously supplied with the necessary materials such as stabilizing agent(s), granular materials, and compaction water. Daily requirements for these materials need to be determined in advance and procedures need to be in place to see that they are supplied without interruption. On large projects or when supply lines are long, temporary storage facilities near the project are established to protect against supply delays and to increase production.

4.0 PULVERIZATION

The preferred way to start the very first pulverization pass of an asphalt surfaced roadway is to have the reclaimer make a preliminary cut from the roadway shoulder perpendicular to the direction of the succeeding passes.

Roadway and reclaimer widths do not normally match, and several passes are required to pulverize the roadway treatment width. This results in a series of longitudinal joints and some overlap between passes is usually required. The minimum overlap width is normally 100 mm but this is sometimes increased to take into account:

• Treatment depths in excess of 300 mm
• Coarseness of the reclaimed materials
• Type of stabilizing agent(s) being used
• Time lapse between adjacent passes

The width of the overlap generally is increased with: increasing layer thickness; reclaimed material coarseness; when working with cementitious stabilizing agent(s) and; where the first pass was made more than twelve hours before the adjacent pass, particularly when using stabilizing agent(s).

The gradation of the reclaimed material should be checked after pulverization to ensure it corresponds to the gradation used in the mix design. Reclaimers are not crushers and will not reduce the pavement layers to sizes smaller than the original aggregates. The gradation of the reclaimed material can be controlled by the operation of the reclaimer.

The gradation of the reclaimed material is influenced by the:

• Front and/or rear door opening on the pulverization/mixing chamber
• Position and/or breaker bar setting of the pulverization/mixing chamber
• Rotation speed of the cutting drum
• Forward speed of the reclaimer
• Condition of the existing pavement
• Ambient temperature - Typically, the most efficient temperature for sizing of the reclaimed material is between 10 and 30°C.

The reclaimed material tends to migrate down-slope when the reclaimer is operating on a super elevation. This phenomenon becomes more apparent, the greater the cross -slope and the thinner the treatment depth becomes. A motor grader is used to blade the reclaimed material back into place before the adjacent pass is made with the reclaimer thereby maintaining the roadway shape and ensuring an adequate longitudinal joint.

5.0 MIXING AND PLACEMENT

When additional pulverization or mixing passes are required to obtain the required gradation or to increase uniformity, the reclaimed material should be lightly compacted and reshaped. This is required to more accurately control the mixing depth, since the rear wheels of the reclaimer compact or reduce the thickness of the fluffed up reclaimed material during the pulverization pass. With light compaction and then reshaping, the reclaimed material will be uniform in thickness allowing the treatment depth to be better controlled. The most frequent error made during the mixing passes is incorporation of subgrade soil into the reclaimed mix by operating the cutting drum at too great of a depth. Care should be taken to ensure that the depth of the pulverization pass is between 25 and 50 mm less than the final mixing pass. This will reduce the risk of a thin layer of untreated reclaimed material being left beneath the stabilized layer.

Light compaction and reshaping also should be undertaken when stabilizing agent(s) are being added. The light compaction will provide a solid working platform for the reclaimer, water truck, and/or stabilizing agent tankers, allowing for a more consistent working speed. Reshaping will permit more accurate control of the treatment depth and application of the stabilizing agent(s).

Various types of reclaimers will place the pulverized and mixed reclaimed material in different ways. Most often, the cutting tools on the reclaimer’s cutting drum are arranged in a chevron pattern to promote mixing. Lateral movement of the reclaimed material is minimal. The reclaimed material exits from the pulverization/mixing chamber rear door, spread across the width of the pass being struck off and smoothed out by the bottom edge of the rear door. The shape of this initial placement of the reclaimed material is dictated by the reclaimer since the rear door is attached to the pulverization/mixing chamber.

The motor grader is used to move and place the reclaimed material to the desired longitudinal grade and cross-slope. The amount of motor grader work required to place the reclaimed material will depend on the original shape of the roadway, the specified final shape of the roadway, and on the type of wearing surface which will be used.

The motor grader should be used judiciously and be carefully supervised. Some reclaimed materials have coarse gradations, particularly for projects in which the asphalt layers were very thick and these materials can be easily segregated.

At the end of the tight blading or trimming of the reclaimed surface, any excess material should be removed. Extreme care must be taken to ensure that shallow depressions are not filled with thin lenses of uncompacted reclaimed materials which are not bonded to the underlying mix.

6.0 APPLICATION OF THE STABILIZING AGENT

If stabilizing agent(s) are required to improve the physical properties of the reclaimed mix, they can be added in a number of ways and locations. How and when the stabilizing agent(s) are added depend primarily on the:

- Type of stabilizing agent(s) being used
- Form of the stabilizing agent(s), i.e., dry, liquid or slurry
- Availability of equipment
- Desired end result

Addition of the stabilizing agent(s) during the pulverization pass, using the reclaimer's onboard additive system, eliminates some or all of the subsequent mixing passes. This has a corresponding reduction in production costs and works well if the existing roadway is uniform in surface condition, material thickness, material composition, and no undetected buried utilities/castings are encountered. In order to maintain a uniform application of the stabilizing agent(s) the following three variables must be held as constant as possible:

- Operating speed of the reclaimer
- Volume or depth of the layer being treated
- Amount of stabilizing agent(s) being added

Stabilizing agent(s) that traditionally have been added in a dry state are now more frequently being added in the form of slurry. The dry stabilizing agent is premixed with water to form slurry which has water content at or slightly below the amount which would be required to bring the reclaimed material to the OMC or 75 percent saturation whichever is less. The slurry is then controlled and injected into the pulverization/mixing chamber by the reclaimer's onboard liquid additive system. Application of the dry stabilizing agent as a slurry eliminates the environmental effects, particularly wind and rain, and can be a more accurate application method.

Normally cement is spread mechanically. Manual spreading of cement bags set out on a grid pattern is only feasible where labour is un-expensive and easily available, but it should be limited to low-traffic roads. If the cement is spread mechanically as powder, the equipment controlled by weight should be used where application rates are regulated by the forward speed. The cement should be dispersed as evenly as possible over the surface to be recycled. In order to minimise cement losses caused by the wind and the consequent discomfort to workers, it is important to synchronise the cement-spreading equipment and mixing equipment so that the length of cement spread ahead of the recycler is as short as possible.

7.0 TRIMMING AND COMPACTION

The trimming operation must be performed as soon as possible after the initial compaction. It may be difficult to carry out it even if a relatively short period is allowed to elapse, since the material hardens rapidly. Once trimming has been completed, compaction proceeds until the required density

is obtained. In this step, rollers work on a surface whose evenness has been corrected by the grader and, in addition, their imprints is far reduced in comparison to those produced in materials that have just come out of the recycler. Therefore, the evenness of a trimmed surface is usually better than in the case such operation is not performed. The time needed for these operations must be taken into consideration when estimating the workability time required for recycling. In addition, the thickness of material behind the recycler must be increased by I00 to 200mm, to take into account that eliminated when trimming.

Compaction should be conducted as quickly as possible after mixing, for the following two reasons:

- To make sure that material is not left exposed to drying it is advisable to have equipment available to prevent excessive surface evaporation This could be a simple manual water spray;

- The workability time of recycled material tends to be relatively short (in favourable conditions never more than 2 to 3 hours, depending on the type of cement used and-on the ambient temperature), unless special road binders or setting retarders are used. Above all, it is important that the recycled material laid in one pass does not start to harden before the next strip of material has been treated and compacted.

Adequate compaction is vital to obtaining the correct strength and durability of the recycled pavement. It is advisable to reach 100% of the maximum Modified Proctor or AASHTO density, with an average of 97% throughout the recycled layer. This requires the use of powerful equipment, particularly where thick layers are recycled, which is the usual case. Reclaimed mixes which are poorly compacted:

- Can densify under traffic which may result in rutting
- Will not achieve early strength gain which may result in surface raveling
- Will not achieve the ultimate strength gain which may result in premature failures

The characteristics of the reclaimed mix will determine whether padfoot, smooth drum, and/or pneumatic compactors should be used. The depth of the reclaimed mix being compacted and the desired degree of compaction will influence the weight and amplitude/frequency of vibration for vibratory Smooth vibrating rollers are most frequently used due to their versatility and efficiency as shown in Table 2.[1]

Table 2. Classification of smooth drum vibrating rollers

Vibrating Roller Type	Static Mass per cm of vibrating drum (N)	Suitable layer thickness (mm)
Light	100 – 200	100 – 150
Medium	200 – 400	150 – 250
Heavy	> 400	250 - 400

As with other construction materials, it is also possible to over-compact a reclaimed mix, particularly if stabilizing agent(s) have been used. This reduction in compaction is more prevalent when vibratory compactors are being used. Generally, it is not necessary to loosen or remix the over-compacted area, but a smaller pneumatic compactor or vehicle traffic is used to seal the transverse check-cracking associated with over compaction.

Experience has indicated that compaction of reclaimed mixes stabilized with asphalt emulsion should be complete at or just after the emulsion starts to break, or when the reclaimed mix starts to change from a brown to a blacker colour. The moisture content of the reclaimed mix prior to the asphalt emulsion breaking is sufficient to act as a lubricant between aggregate particles, but does not fill the void space between the aggregate particles and prevent densification from occurring. In addition, after the asphalt emulsion breaks, the viscosity increases significantly, requiring additional effort to achieve the required compaction.

Compaction of reclaimed mixes stabilized with foamed asphalt can take place immediately after mixing, assuming it is at or near the optimum fluid content for compaction. Reclaimed mixes stabilized with foamed asphalt will remain workable, providing the moisture content stays at or above the moisture content at the time of the foamed asphalt injection and mixing. Ideally, the compaction process should be completed before the foamed asphalt stabilized mix starts to dry out.

Cementitious stabilized mixes need to be compacted in as short a period of time as possible since the hydration process begins as soon as there is moisture available. Specifications traditionally indicate that the total time for mixing, placing, compacting, and finishing the cementitious stabilized mix be less than a specific time period, usually between two to four hours. The two to four hours is usually measured from the time the stabilizing agent first is exposed to moisture to the time compaction is complete. With a modern reclaimer this time limit is usually not difficult to achieve, provided the length of the segment being treated is appropriate for the available equipment.

8.0 CURING AND PROTECTION OF THE RECYCLED MATERIAL

As soon as the final compaction has been completed, the recycled layer should be cured to protect the material from moisture losses, weather and traffic.

It is generally best to keep traffic off the pavement during curing. However, this can almost never be accommodated. The opening of the recycled surface to traffic should be delayed until the curing emulsion breaks, and precautions must be taken to make sure that the traffic speed is moderate, in order to prevent deterioration.

The bituminous surfacing can also be placed immediately after curing, but it is advisable to delay this operation at least seven days to obtain a more adequate development of the joints and/or shrinkage cracks system.

Reclaimed materials that have been stabilized by chemical, bituminous or a combination of these stabilizing agents need to be properly cured to:

- Achieve the ultimate strengths
- Prevent raveling under vehicle traffic
- Facilitate placement of the wearing course

Curing can be divided into three categories: initial; intermediate; and final. Initial curing is relatively short and permits the stabilized mix to gain sufficient cohesion to be less susceptible to surface disturbance. Time for initial curing can be shorter than half an hour for foamed asphalt stabilized mixes and an hour or more for asphalt emulsion stabilized mixes. Initial curing times for cementitious and combination stabilizing agents usually fall between these two limits. Initial curing times depend almost entirely on the amount and type of stabilizing agent(s) used and very little on the ambient conditions.

Generally, the surface of the reclaimed mix is dampened with a light application of moisture, and the surface tightened with a pneumatic roller, as the last stage of compaction and the first stage of initial curing. During the initial curing period, all vehicle traffic is kept off the area or it is severely restricted, depending on the characteristics of the reclaimed mix. At the end of the initial curing period, the roadway can be opened to light vehicle traffic.

Intermediate curing is more extensive in length, and depends almost equally on the amount and type of stabilizing agent used and ambient conditions. Intermediate curing is required, to allow the reclaimed mix to build up sufficient strength and/or to allow sufficient moisture or volatiles to escape to permit the wearing course to be successfully applied. With the increased use of lime or Portland cement to accelerate initial curing and strength gain, it may no longer be an adequate measure, as field strength does not correlate well with moisture content. As a rule of thumb, whenever a core can be extracted from the reclaimed mix relatively easily, it usually has developed enough strength and lost sufficient moisture to be covered by the wearing course.

Final curing is the time it takes the stabilized mix to reach its ultimate strength, and can be a very long period. Final curing takes place after the wearing course has been applied and is dependent on the amount and type of stabilizing agent and ambient conditions. For some stabilizing agent(s) it can be measured in months or years.

9.0 COST ANALYSIS

Since the deterioration models for FDR pavement stabilized with various stabilizing agents have not been established up to this stage, the cost analysis was based on initial construction cost for different treatment types. It was noted that FDR with cement as stabilizing agents yielded the lowest cost ratio relative to the control section, followed by FDR with lime, FDR with foamed bitumen and finally FDR with bitumen emulsion (Figure 5).Apparently with different types of stabilising agents, the initial cost will be reduced from 10% - 50% depends on the agents.

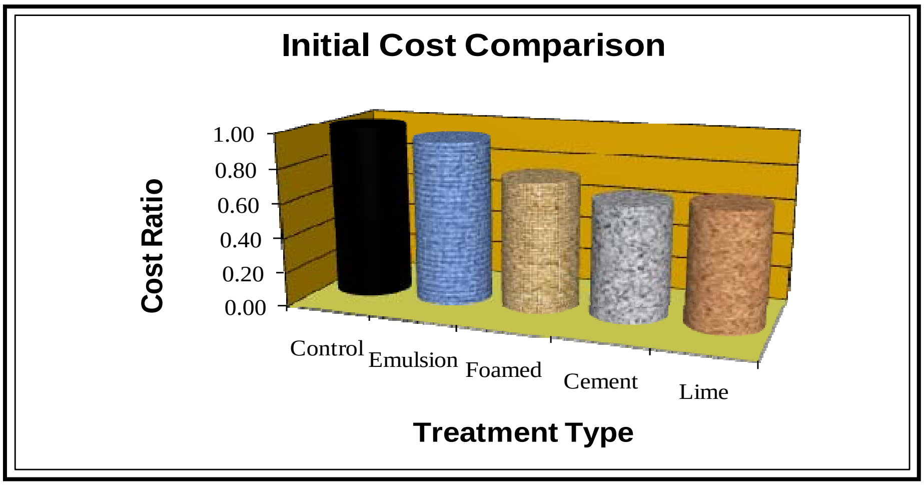


Figure 5. Comparison of initial cost for each type of stabiliser agent

10.0 CONCLUSIONS

Although CIPR is relatively new in Malaysia when compared to some Western countries, by experience it has proven that the technique presents a cost- effective and viable means of pavement rehabilitation. CIPR projects implemented as far back as 20 years ago are still exhibiting good pavement condition. The most recent CIPR projects have demonstrated that a cost saving of up to 40% is achievable compared with the conventional rehabilitation methods especially conservation in time, materials, binders and energy. This technique operating with low initial cost prior to the minimum open excavation and does not required large dumping area as compared to the conventional method. The number of dump truck to transport the unsuitable materials from the site can be reduced. Practically CIPR will leads to the preservation of the environment and with the proper process and method it will maintains the ecosystem of the construction area. Furthermore, the strength of the recycled layer can gives equivalent strength as to conventional technique which more flexible and fatigue resistant.

Due to the many demonstrated advantages of CIPR, Malaysia is now keener to evaluate and improve further with the aim to make recycling a norm rather than an option in future rehabilitation projects. A full research is currently underway that focuses on the deterioration of pavement material, moisture levels, aggregate gradations, stabilizer types and construction methods. This research will be completed by 2009 and the results of this research will be the foundation for producing Malaysian guidelines for recycling works.

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